The goal-free effect

Fred Paas
University of Wollongong, fredp@uow.edu.au

Femke Kirschner
Erasmus University of Rotterdam

GOAL-FREE EFFECT

Fred Paas
Institute of Psychology, Erasmus University Rotterdam
Rotterdam, The Netherlands
paas@fsw.eur.nl
Faculty of Education, University of Wollongong
Wollongong, Australia

Femke Kirschner
Institute of Psychology, Erasmus University Rotterdam
Rotterdam, The Netherlands
kirschner@fsw.eur.nl

Synonyms

No-goal effect; Reduced goal-specificity effect

Definition

Research on learning from solving transformational problems has shown that the extent to which a goal is clearly specified to a problem solver as a problem state affects the problem-solving strategy used. Transformational problems are characterized by an initial problem state, a goal state, and a set of operators to transform the initial problem state into the goal state. Under goal-specific conditions novice problem solvers work backward from the goal setting subgoals until equations containing no unknowns other than a desired goal state are encountered (i.e., means-ends analysis). Under nonspecific goal conditions novice problem solvers work forward attaining the desired goal by choosing equations which allow a value for an unknown to be calculated (i.e., history-cued strategy). The goal-free effect refers to the finding that practicing by solving problems with a nonspecific goal imposes a lower cognitive load and leads to better learning than practicing by solving problems with a specific goal.

Theoretical Background

Problem solving research has found that reducing the specificity of problem goals facilitates learning of novices during problem solving (e.g., Paas, Camp, & Rikers, 2001; Sweller, 1988; Sweller & Levine, 1982; Sweller, Mawer, & Ward, 1983). Practicing by solving problems with a nonspecific goal (e.g., A car uniformly accelerates from rest for 1 min. Its final velocity is 2 km/min. Calculate the value of as many variables as you can.) imposes a lower cognitive load and leads to better learning than practicing by solving problems with a specific goal (e.g., A car uniformly accelerates from rest for 1 min. Its final velocity is 2 km/min. How far has it traveled?). Initially, the effect was theoretically explained by Cognitive Load Theory (Sweller, 1988). Cognitive load theory posits that specific goal problems focus attention on differences between the current problem state and the goal state, thus encouraging use of a means–ends analytic strategy. Means–ends analysis involves reducing differences between the current state and the goal state by applying legal operators (e.g., equations) until the goal state is achieved. Problem-solving search through means-ends analysis is an efficient way of attaining a problem goal in the absence of a schema (i.e., for novices). Nevertheless, it is a process that is exceptionally expensive of working memory capacity because problem solvers must maintain information regarding the current problem state, the goal state, the relation between the current problem state and the goal state, the relations between problem-solving operators and, lastly, if subgoals have been used, a goal stack in working memory. Thus, if much of the limited cognitive resources of learners are devoted to using the means–ends strategy, few resources are available for more general learning (i.e., schema construction). Nonspecific goal problems, on the other hand, eliminate means–ends search and its attendant cognitive load because the ultimate goal state is not specified. Nonspecific goal problems encourage a forward solution or history-cued strategy in which current problem states are compared with possible operators until an immediately applicable operator is found. This process continues until no further applicable operators are found. Whereas means–ends analysis requires that the current state, the goal state, subgoal states, and operators be kept in working memory, a forward solution strategy requires only that the current state and possible operators be kept in working memory. Thus, nonspecific goal problems encourage the less resource-demanding forward solution strategy, thereby freeing up resources that can be used for schema construction (i.e., learning).

Alternative theoretical explanations of the goal-free effect are related to attentional focus and dual-space search. According to Trumpower, Goldsmith, and Guynn's (2004) attentional focus perspective, a nonspecific goal is considered to foster learning of local relations between successive problem states by focusing attention on the immediate effect of operators. A specific goal is believed to encourage learning of more distal relations between current states and the goal state, at the expense of learning local relations.

Using dual-space theory of problem solving, Burns and Vollmeyer (2002) consider specific goals as encouraging search of an instance or experiment space because a specific goal is a state in such a space. In contrast, a nonspecific goal is considered as encouraging search of rule or hypothesis space. Such a search space contains the possible rules or hypotheses that may govern the task, but testing such rules requires a coordinated search of instance and rule space.

Important Scientific Research and Open Questions

Many experiments have demonstrated the effectiveness of goal-free problems as an instructional design tool. Sweller, Mawer, and Ward (1983) ran several experiments using kinematics and geometry problems with secondary students. The kinematics problems were similar to the one used as an example above. The geometry problems used theorems such as vertically opposite angles are equal and the external angles of a triangle equal the sum of the opposite internal angles. Conventional geometry problems required students to find a value for a particular angle in a diagram, whereas goal-free problems asked students to find the values of as many angles as they could. The general procedure was to provide a conventional group with relevant instruction in kinematics or geometry, followed by an acquisition phase involving practice at solving conventional problems. An identical procedure was followed by the goal-free groups except that the practice session used goal-free rather than conventional problems. Common tests using conventional problems were then used to assess learning. Results consistently indicated that the goal-free groups were superior in terms of schema construction. Ayres (1993) found that on two-step geometry tasks with conventional problems, most errors occurred during the subgoal rather than the goal phase. Working memory load was highest at the subgoal phase, because more elements must be considered at this phase than at the goal phase. In contrast, fewer errors were made by students practicing on goal-free problems with the reduction due to a reduction of working memory load during the non-existing subgoal phase. Vollmeyer, Burns, and Holyoak (1996) used biology-based problems to demonstrate that learning was retarded when tertiary students solved problems using means-ends analysis compared to goal-free strategies. Using a computerized maze-tracing task, Paas, Camp, and Rikers (2001) compared the learning performance of young and old adults in a goal-specific and goal-free condition. They found that the presence of a specific goal compromised learning performance, especially for older adults. Based on those results they concluded that the use of goal-free instruction could compensate for age-related cognitive declines. In the domain of quantitative methods Trumpower, Goldsmith, and Guynn (2004) found that structurally different transfer problems were solved faster after solving problems with nonspecific goals than after solving problems with specific goals. In a study by Wirth, Künsting, and Leutner (2009) students could conduct experiments in a computer-based environment to learn about buoyancy in liquids. They found that students who were provided with nonspecific problem solving goals reported lower cognitive load and learned more than students who were provided with specific problem solving goals.

Evidence for the effectiveness of goal-free problems is strong, with the effect obtained under a very wide variety of conditions. We believe there are cogent grounds for instructing novice learners in areas such as mathematics and science to reduce the goalspecificity of problems before solving those problems (e.g., if the goal of a problem is to 'calculate a specific variable', transform this goal into 'calculate the value of as many variables as you can'), and for encouraging instructional designers to consider including goal-free problems in their repertoire of techniques when dealing with those areas in which practice at solving problems is an important instructional procedure.

Cross-References

Cognitive load theory
Problem solving
Working memory

References

Ayres, P. (1993). Why goal-free problems can facilitate learning. *Contemporary Educational Psychology, 12*, 376-381.

Burns, B. D., & Vollmeyer, R. (2002). Goal specificity effects on hypothesis testing in problem solving. *Quarterly Journal of Experimental Psychology, 55A*, 241–261.

Paas, F., Camp, G., & Rikers, R. (2001). Instructional compensation for age-related cognitive declines: Effects of goal specificity in maze learning. *Journal of Educational Psychology, 93*, 181–186.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*, 257–285.

Sweller, J., & Levine, M. (1982). Effects of goal specificity on means-ends analysis and learning. Journal of Experimental Psychology: Learning, memory, and Cognition, 8, 463-474.

Sweller, J., Mawer, R. F., & Ward, M. R. (1983). Development of expertise in mathematical problem solving. *Journal of Experimental Psychology: General, 112*, 639–661.

Trumpower, D. L., Goldsmith, T. E., & Guynn, M. J. (2004). Goal specificity and knowledge acquisition in statistics problem solving: Evidence for attentional focus. *Memory & Cognition, 32*, 1379-1388.

Wirth, J., Künsting, J., & Leutner, D. (2009). The impact of goal specificity and goal type on learning outcome and cognitive load. *Computers in Human Behavior, 25*, 299-305.